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Report on Gear Evaluations to Mitigate Sea Turtle Capture and Mortality on Pelagic Longlines using Captive Reared Sea Turtles

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Introduction

Incidental takes of sea turtles listed under the U.S. Endangered Species Act (ESA) have been documented in longline fisheries in the Pacific, Atlantic, and Gulf of Mexico . These fisheries are responsible for capturing and/or killing several species of sea turtles. The species that are primarily impacted by these fisheries are the loggerhead sea turtle (*Caretta caretta*) and the leatherback sea turtle (*Dermochelys coriacea*) These species are captured on longlines and often released injured or dead.

Fisheries independent research is being conducted to determine why and how sea turtles are interacting with longline gear. From this research, fishing methods and/or fisheries gear may be developed to try to reduce the number of incidental captures and lessen the damage done to turtles that are captured. Researchers are attempting to learn as much as possible about turtle behavior around longlining gear to lessen their interaction with the gear. Researchers would also like to decrease the incidence of deep hooking in turtles. It is believed that sea turtles which are deeply hooked, i.e. hooked in the throat or gut, have a greater incidence of mortality compared to those turtles hooked in the mouth.

Several groups of researchers are addressing these problems, including the Harvesting Systems and Engineering Division of NMFS, Mississippi Laboratories. This group includes Fishery Biologists, Fisheries Methods & Equipment Specialists, and Engineers. The NMFS Galveston, TX laboratory has a facility where sea turtles are raised from hatchlings for use in TED (Turtle Excluder Device) testing, These turtles are primarily loggerhead sea turtles. The turtles are raised for two to three years before being used for TED testing. There were some additional turtles available this year which were used in longlining tests. These turtle were used in a variety of tests to better understand their behavior when exposed to longlining gear. This report provides a summary of work conducted in June and September of 2001 by the NMFS Harvesting Systems Branch, Pascagoula, MS.

Project Objectives

Conduct a series qualitative and quantitative experiments within the NMFS Panama City sea turtle containment pens to:

1) Determine if captive reared sea turtles are attracted to floats used in the pelagic longline fishery

2) Observe and compare sea turtle interaction/avoidance and degree of entanglement with monofilament line currently used in the pelagic longline fishery versus "stiffened" gear.

3) Conduct an assessment of deep hooking avoidance devices to prevent deep hooking of sea turtles on pelagic longline gear.

4) Test the effectiveness of various devices to deter sea turtles from interacting with longline gear.

Turtles

Tests and evaluations of turtle behavior were conducted during June and September 2001. During the June project, turtle/longline evaluations were conducted in conjunction with the NMFS annual TED testing project. For this combined work, a total of 180, 1999 year-class Florida loggerheads were used in the tests/evaluations. The turtles had a mean straight line carapace length (SLCL) of ~36 cm. Acclimation and conditioning of the turtles was conducted for 4 weeks prior to the tests/evaluations within the turtle pens located at the NMFS Panama City laboratory. Care and maintenance of the test turtles during the conditioning period and throughout the project was the responsibility of on site personnel from the NMFS Galveston, TX laboratory. At the conclusion of the June project, NMFS Galveston transported 78 turtles back to their holding facilities for use in additional work in September. The remainder of the turtles were released in Florida state waters according to state recommendations. The 78 turtles held in Galveston though the summer were transported back to Panama City, FL on September 12. The mean straight-line carapace length for the turtles used in the September project was 40.9 cm. All turtles were released into Florida state waters at the conclusion of the September project.

Project Summary

The format of this report will provide the objectives, methods and results for each test/evaluation individually.

Float Attraction Evaluation #1
Objective: *Determine if captive reared sea turtles are attracted to floats used in the swordfish longline fishery.*

Methods
This evaluation was conducted during June, 2001. A 30 ft. by 80 ft. rectangular pen was built in St. Andrews Bay adjacent to the West pier of the NMFS, Panama City, FL laboratory. The pen has a water depth which ranges from 2 to 6 ft. On the eastern edge of the pen, ten (10), 3 ft. by 3 ft. holding pens with release doors where built to allow the turtles to swim into the larger pen. Two video cameras were positioned above the pen pointing straight down. The field of view of each camera covered almost one half of the pen area. Each video camera was hard wired to a video monitor and VCR. The monitors and VCRs were located in a small trailer where an observer was posted to observe every trial and record the time of each encounter on a data sheet.

The pen was visually divided in half (side A and side B, Figure 1). A single float was placed in the center of side A or B. A turtle would then be released into the pen and the observer would record the location of turtle in the pen. These observations were categorized into (A), contact with the float (B), turtle on the surface, or (C), turtle underwater. This was recorded for both the side with the float and the side without the float.

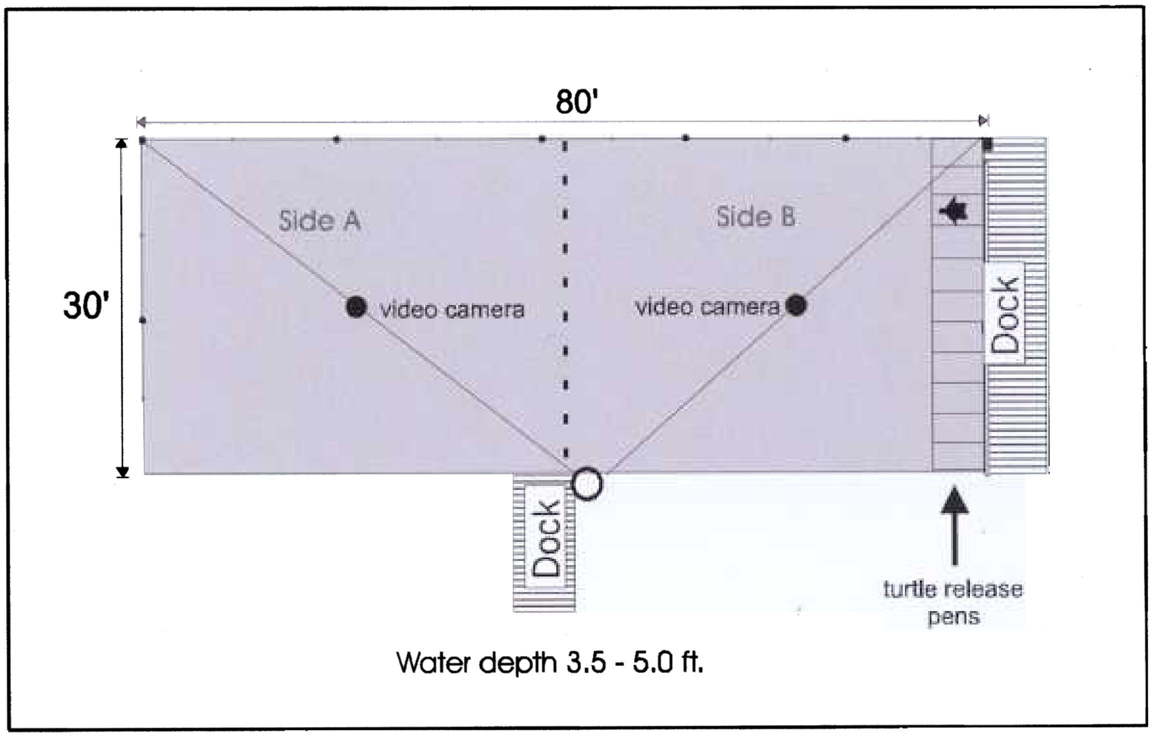

Figure 1 Experimental pen: overhead view

Three types of floats were evaluated: an orange bullet float, a white bullet float, and an orange poly float. These are the most predominately used floats in the fishery. The float type and side of the pen where the float was placed was randomly chosen by a coin toss.

Results

The results from this evaluation are provided in Table 1.

Orange Bullet vs.	Control	White Bullet vs.	Control	Orange Poly vs.	Control
51/4	27/0	45/0	43/0	8/0	8/0
n = 35		n = 42		n = 10	

Table 1 Turtle attraction to longline floats. Data presented as total number of encounters /contact with float

The results show more occurrences in the area containing the orange bullet float than the corresponding control area (51 vs 27). Although there were very few actual contacts of the turtle with the float is was difficult to determine from observations with the video camera if the turtles were investigating the orange float or just swimming through the area underneath the float. There were slightly more occurrences of turtles in the area of the white bullet float than in the corresponding control area (45 vs 43).

Float Attraction Evaluation #2
Objective: *Compare conditioned turtles to non-conditioned turtles (control) in their attraction to longline floats.*

Methods
This evaluation was conducted during September, 2001. This test was conducted to determine if turtles which had been conditioned to feed under floats would be more attracted to floats than turtles which had never been fed under floats (non-conditioned). Prior conditioning was conducted at the turtle facility at the NMFS, Galveston, Texas laboratory by placing a squid on a carabineer attached to a white bullet float. Conditioned turtles were fed this way for two weeks, one feeding per day. The non-conditioned control group was fed normally by tossing squid into the tank.

This evaluation was conducted similarly to the test conducted in June, however the turtles had less time to acclimate in the holding pens prior to September testing. A total of 15 conditioned turtles and 15 non-conditioned turtles were tested. The two different groups were released alternately. After every two turtles, the float position was swapped. The float used for this test was a white bullet float. Turtles were scored and videotaped just as in the June tests. Turtles were scored as having entered the float "area" when they came within view of the overhead video camera positioned directly over the float. This area measured approximately 347 sq feet (106 sq meters) or a rectangular space measuring 23.8 feet by 14.6 feet (7.2 m x 4.5 m).

Results
The results showed 46 occurrences of conditioned turtles in the area of the white float versus 39 occurrences in the area without the float (Table 2). The non-conditioned turtles were observed in the white float area and the non-float area equally (43 each). There was no actual contact with the float with either group during this test.

Occurrence of Conditioned Turtles		Occurrence of Non-conditioned Turtles	
Area w/ float	Area w/o float	Area w/ float	Area w/o float
46	39	43	43
n = 15		n = 15	

Table 2 Turtle attraction to floats: Comparison of conditioned turtles to non-conditioned turtles. Data presented as number of occurrences in close proximity to float

Float Attraction Evaluation #3
Objective: *Head to head comparison of orange bullet floats vs. white bullet floats, and comparison of behavior between conditioned and non-conditioned turtles.*

Methods
This part of the float attraction test was a head to head comparison of orange versus white floats comparing their attraction rates. This test was also performed with conditioned and control turtles. The experiment was conducted by randomly selecting a float color and it test position (side A or B), each side containing a different color float. One turtle at a time was released into the pen, and conditioned and non-conditioned turtles were alternated between trials.

After one turtle from each group was released (2 trials) the float position (side) would be swapped. This was done to try to eliminate any side bias that might occur. A total of 30 trials were run, for a total of 15 conditioned turtles and 15 non-conditioned turtles. Each trial lasted 30 minutes. As in the previous tests, all trials were videotaped and scored by an observer.

Results

The conditioned turtles had more occurrences in the orange float side than the white float side (44 vs. 33). The non-conditioned turtles had more occurrences in the white float area than the orange float. (45 vs. 34). The only actual contact with the float was with a control turtle which contacted an orange float.

Occurrence of Conditioned Turtles		Occurrence of Non-conditioned Turtles	
Area w/ orange float	Area w/white float	Area w/ orange float	Area w/white float
44	33	34	45

Table 3 Turtle attraction to floats: Head to head comparison of white floats vs. orange floats for conditioned and non-conditioned turtles.

Float Attraction Evaluation #4

Objective: *Compare attraction of white floats with AK snaps attached below them to white floats without AK snaps for conditioned and non-conditioned turtles.*

Methods

This evaluation was to examine the possible attraction of turtles to AK snaps commonly used by the pelagic longline fishery. This evaluation was performed by placing a white float in both sides of the pen, one having an AK snap hanging below the float and the other without an AK snap. Again we used conditioned and control turtles. In this evaluation, two white floats were placed in the pen, one in side A and the other in side B. One of the floats had an AK snap attached by monofilament line and hanging 18 inches below the float. Conditioned and non-conditioned turtles were released alternately. After one of each type of turtle was run the float position would be alternated. The number of occurrences on each side was scored by the observer and also videotaped.

Results

This test was limited due to lack of time and inclement weather creating poor water conditions. Only 10 turtles were run in these tests, 5 conditioned and 5 non-conditioned turtles. Therefore the results are not conclusive. The conditioned turtles occurred more often in the area containing the float with the AK snap attached than in the area with the float only. (23 occurrences with the AK snap versus 19 occurrences in the area without the AK snap). With the non-conditioned group of turtles the AK snap side had 21 occurrences versus 19 occurrences in the area without the AK snap.

Occurrence of Conditioned Turtles		Occurrence of Non-conditioned Turtles	
Area w/float & AK snap	Area w/float only	Area w/float & AK snap	Area w/float only
23	19	21	19

Table 4 Turtle attraction to floats: Comparing attraction of turtles to white floats with AK snaps attached below them to white float without AK snaps attached.

Evaluation of Hooking Deterrents
Objective: *Determine if deep hooking avoidance devices are effective at reducing the incidence of deep hooking in turtles and determine what sizes and shapes are effective.*

Methods
Evaluations of deep hooking avoidance devices (DHAD) were qualitative in nature and were aimed at determining if the use of such devices are feasible as a means of preventing deep hooking of sea turtles. These evaluations were conducted in a variety of containment areas. The June tests were conducted in a 7 ft. diameter circular fish tank with a water depth of approximately 4 feet. Additional testing in September was performed in floating pens placed inside the main turtle pens and in the smaller turtle holding basins on the dock. For each series of evaluations, turtles were placed in the containment tank/pen for at least 10 minutes to allow them to settle down before beginning the evaluations.

The DHAD was attached a 600# test monofilament line and crimped into place to keep it from moving on the line. A squid bait was placed below the DHAD and was woven onto the monofilament line. No hooks were used in these evaluations. The trailing end of the mono was usually secured with a crimp or a knot. The baited line was then placed in the pen with the turtle and an underwater video camera was lowered into the pen to record the event.

Four types of devices were evaluated (Figure 2), (1) a disc placed on the line above the bait,(2) a football shaped bait stopper, (3) a clear soda bottle with the bottom cut out which was placed around the bait and (4) funnels placed above the bait. Several variations of the discs were also evaluated. Sizes of the discs ranged from 1 3/8" to 3 1/4". Five colors were evaluated, clear, white, red, black and blue. The hook stoppers were placed from 4 ½ inches away from the bait to zero inches from the bait.

Results
All of the discs were effective at keeping the turtles from deeply swallowing the bait. Hook stopper discs were tested using progressively smaller sizes. During the June testing, disc sizes down to 2 1/8" were tested. None of the turtles were observed to take these discs in their mouths. During the September testing smaller disc sizes were evaluated. We initially evaluated a 1 5/8" disc, these disc were not deeply swallowed but the turtles were able to take the disc into their mouth although they would quickly reject the disc. 1 3/8" disc were also evaluated, as expected these disc could also be taken into the turtles mouth. These disc were taken deeper into their mouth and looked as if they could be a choking hazard. None of the disc seemed to greatly inhibit the turtles from taking the bait but the larger sizes were effective at keeping them from deeply swallowing the bait. The turtles typically would take the bait, then as they attempt to suck the bait down their throat, the stopper disc would contact their nose and/or flippers. When this occurred, the turtle would be startled and would allow the bait to partially come back out of their mouth or push the bait out of its mouth with its flippers. The turtle would then continue to suck the bait back in, until the DHAD again contacted its nose or flipper. This would occur repeatedly until finally the turtle would give up and let go of the bait. It appeared as though the turtles did not see the clear disc but only felt it with their nose and flippers.

The behavior was similar with disc of all colors but the turtles were somewhat more apprehensive about initially taking the bait with the blue disc above them. The size of the disc made no observable differences as to whether the bait was taken or not, or how soon they gave up on trying to swallow the bait. Obviously the disc needs to have a diameter large enough so that the turtle cannot swallow the disc. Minimum disc size should probably be at least 13/4 inch to 2 inches.

The football shaped hook stopper was also effective at keeping the turtles from deeply swallowing the bait. This device worked similar to the disc in that it did not deter the turtle from taking the bait, yet didn't allow the turtle to deeply swallow the bait. Only one test was run with the soda bottle cover over the bait. In this test the turtle did not hesitate to take the bait, but it became distressed when the bottle poked it in the face and it gave up the bait.

The funnels also seemed to be effective at decreasing deep hooking of turtles. Funnels were placed above the bait with the flared or bell end of the funnel toward the bait and the tapered or tip end of the funnel toward the bait. Placing the bell end toward the bait seemed to be more effective since when reversed the turtles occasionally would chew on the tip or taped end. This arrangement may also be preferable to the fisherman when hauling back the gear in that it would create less drag in the water.

Intuitively, it would probably be beneficial for the turtle to have the stopper disc or other deterrent as close as possible to the bait to avoid deep hooking. Additionally, de-hooking would be easier for the fisherman if the turtle were hooked in the anterior portion of the mouth. For these small to medium sized turtles these devices would probably prevent a deep throat or gut hooking of a turtle. Evaluations need to be conducted to determine if the target species will take the bait with these deep hooking avoidance devices attached.

<u>Underwater Visibility of Colored Monofilament</u>

Objective: *Determine which colors and diameters of commercially available monofilament are least visible and most visible underwater.*

<u>Methods</u>

An evaluation of various colors and diameters of monofilament line was conducted by building a square metal frame which had a video camera attached to it and monofilament line strung perpendicular to the camera (Figure 3). The test was conducted approximately 10 miles offshore of Panama City, FL in depths of 80 ft. The frame was lowered to a depth of approximately 50 feet for the tests. The water color was mostly blue with a slight greenish tint. The camera was hard wired to a videocassette recorder on the deck of the boat. Each trial was recorded.

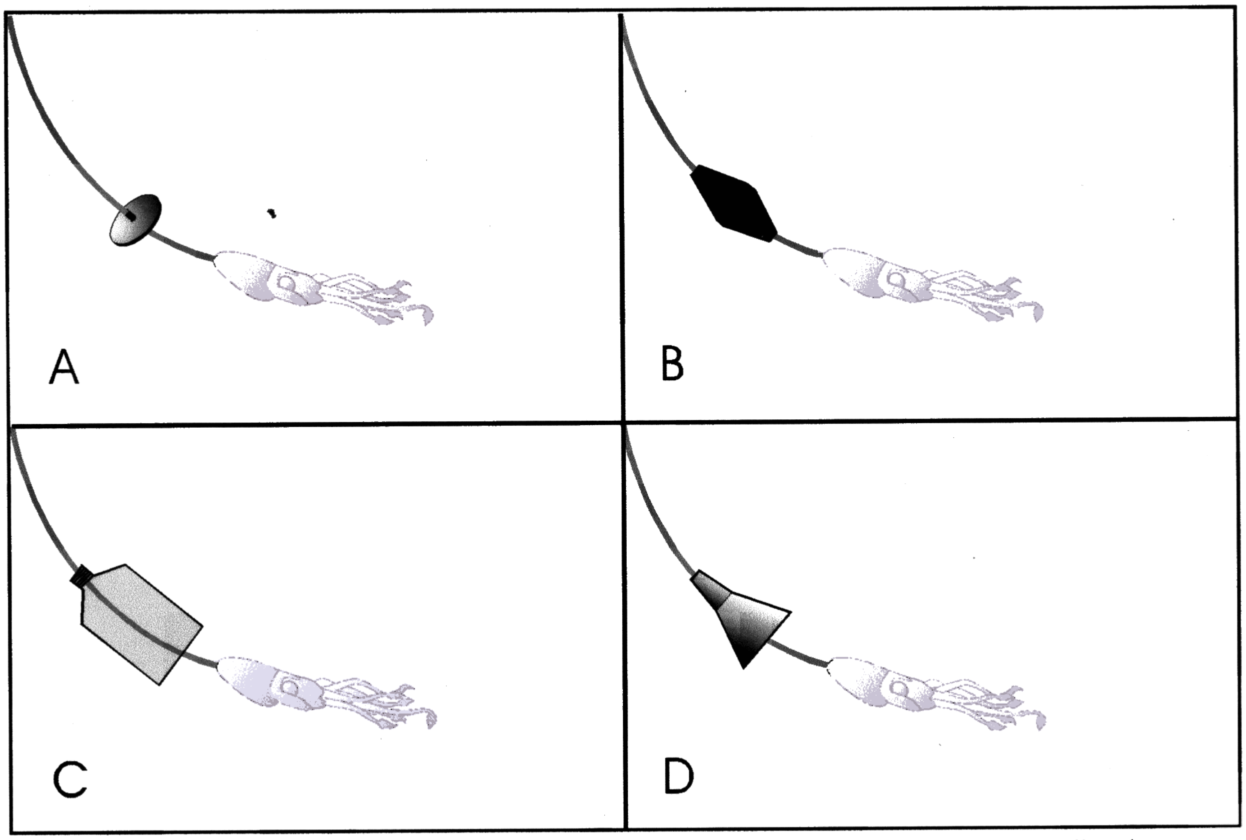

Figure 2 Deep hooking avoidance devices evaluated during June & September 2001. A: Disc, B: Fiberglass football shape, C: Soda bottle with bottom cut away and D: Plastic Funnel

The colors and sizes evaluated were Clear (400 # test), Gray (400# test), Red (500# test), Clear/Natural (600# test), Dark Blue (500 # test), Smoke Blue (400# test), and Black (400# test).We observed the lines from five different angles with respect to the surface (Figure 3), (1) looking straight down (180 degrees), (2) 90 degree angle, (3) looking down at a 45 degree angle, (4) looking up at a 45 degree angle, and (5) looking straight up (0 degrees). Monofilament types were categorized according to their visibility and their lack of visibility. The lines were also ranked within each category depending on level of visibility. For example, in least visible category a score of 10 would be almost invisible, and a score of 10 in the most visible category would be highly visible. The scores are in parenthesis following the color name.

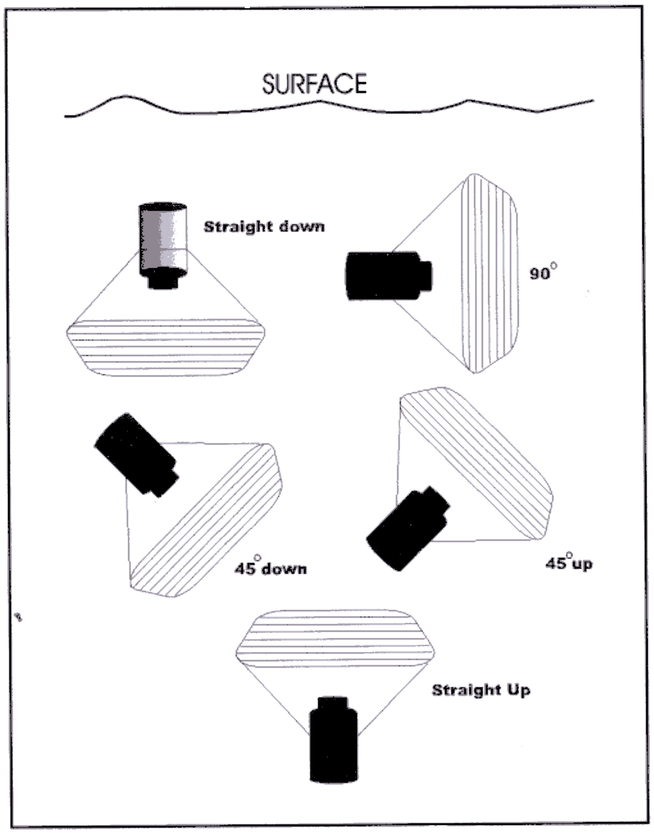

Figure 3 Monofilament visibility test.

Results

The results of the monofilament viability evaluations are shown in table 5. Based on these evaluations, in order to make droplines least visible the preferred colors would be gray, clear, or dark blue. Since the droplines are oriented vertically, turtles might be more likely to view them from straight on (90 ^{0}), or looking down at them from an angle when the turtle is swimming on the surface. The mainline, oriented horizontally, should probably be smoke blue, black, or dark blue since it probably would be seen by a turtle looking straight down or down at an angle. Observations on most visible monofilament line was also recorded in case our focus shifts from stealth gear to highly visible gear. As would be expected, larger diameter lines are much more visible than smaller diameters.

Table 5 Underwater visibility of colored monofilament as observed from various angles

	Least Visible	Most Visible
Straight Down	1. Smoke Blue (10) 2. Black (9)	1. Clear (600 #) (10) 2. Red (8) 3. Dark Blue (7)
90 ^{0}	1. Gray (10) 2. Clear (400#) (8) 3. Clear (600#) (4)	1. Red (10) 2. Black (7) 3. Smoke Blue (7)
45 ^{0} down	1. Dark Blue (9) 2. Gray (6) 3. Clear (400#) (6)	1. Red (10) 2. Clear (600#) (9) 3. Smoke Blue (4)
45 ^{0} up	1. Gray (10) 2. Clear (400#) (9) 3. Clear (600#) (8)	1. Red (10) 2. Dark Blue (8) 3. Smoke Blue (7)
Straight Up	1. Gray (9) 2. Clear (400#) (9)	1. Red (10) 2. Dark Blue (9) 3. Smoke Blue (8)

Observations of captive reared turtle interaction with standard and modified pelagic longline gear

Objective: *1) Observe the behavior of sea turtles when they come in contact with longline monofilament.*

2.) Determine if stiffness of monofilament is correlated to level of entanglement.

3.) Evaluate gear modifications for preventing/reducing entanglement and or foul hooking of turtles.

Methods

A qualitative assessment of sea turtle entanglement with monofilament line was performed by exposing turtles to a scaled version of a pelagic longline set within a 24 m x 7.5 m experimental pen (Figure 4). The pen was subject to tidal fluctuation, thus water depths ranged from 3.0 ft. to 8.0 ft.

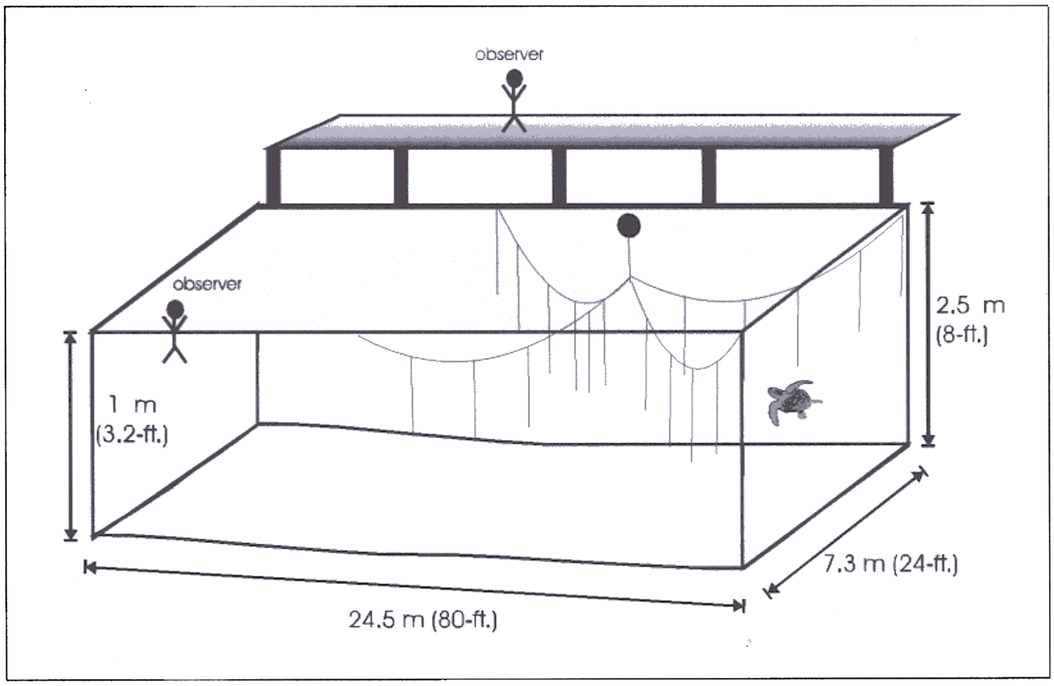

Figure 4 Pen and gear configuration for monofilament entanglement evaluations

Two sections of longline gear including buoy drops and gangions with AK snaps were modeled and scaled down in vertical dimension. The mainline sections were positioned in an "X" configuration across the experimental pen. Treatments included various diameters of monofilament gangions, weights, hook deflecting devices. On to each gangion was crimped a barb-less modified hook 9/0 J-hook (Figure 5).

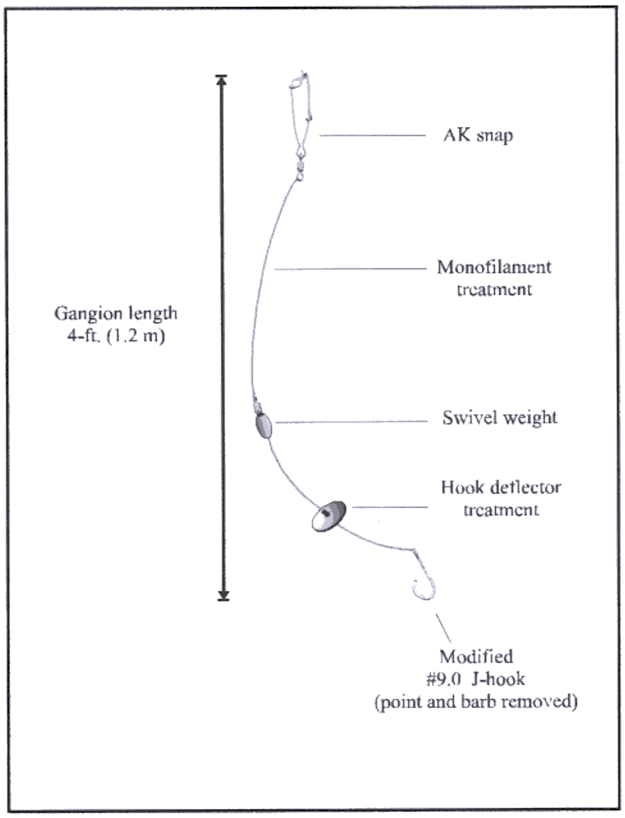

Figure 5 Gangion configuration used for entanglement observations.

Individual turtles were exposed to the treatments for 30 minute periods. An observer positioned on the dock adjacent to the pen monitored the turtles activity and encounters with the longline. A second observer was stationed in the near shore end of the pen with snorkel and mask in order to provide a quick response to a turtle that might be unable to surface after becoming entangled. Turtles which became entangled were allowed to remain entangled for 5 minutes if they were able to surface for air. After the 5 minute period, the in water observer would disentangle the turtle. Turtles which were entangled and were unable to reach the surface were disentangled after 1 minute. The spacing between gangions was approximately 10 feet (3 m). During the 30 minute exposure period, we recorded "events" as follows: *1.) Rolled Off*: a turtle encountered the gangion, but the monofilament rolled off the end of the flipper. 2.) *Entangled* : the turtle became fouled or wrapped in the monofilament for a minimum period of 15 seconds and 3.) *Hooked* a turtle was considered hooked, if the modified hook came in contact with the flipper or any other soft part of the turtle.

Entanglement Evaluation #1: Monofilament stiffness and turtle entanglement

Gangions treatments were constructed from 2.6 mm, 3.0 mm and 3.6 mm monofilament (3.6 mm being the least flexible or stiffest) without lead weights. Four each of 3.0, and 3.6 mm monofilament gangions were evenly distributed along the 2 legs of the mainline and 8 gangions of 2.6 mm were distributed along the two remaining legs.

Results

The results from this evaluation are presented in Table 5. The n values presented correspond to the number turtle encounters with a given monofilament diameter. Turtles usually encountered the gangions by swimming head first directly into them. As the turtle continued to swim forward, the gangion would typically slide across the shoulder area and over the top of the carapace. In most instances, the turtle did not seem to be disturbed by an encounter until the modified hook eventually touched the flipper or carapace. If the turtle became entangled or hooked, the typical reaction from the turtle was to swim vigorously in a forward direction. This usually caused the entanglement to worsen. Nearly equal numbers of encounters occurred with 2.6 mm and 3.6 mm gangions. The results show that encounters with stiffer monofilament (3.0 mm and 3.6 mm) resulted in fewer entanglements.

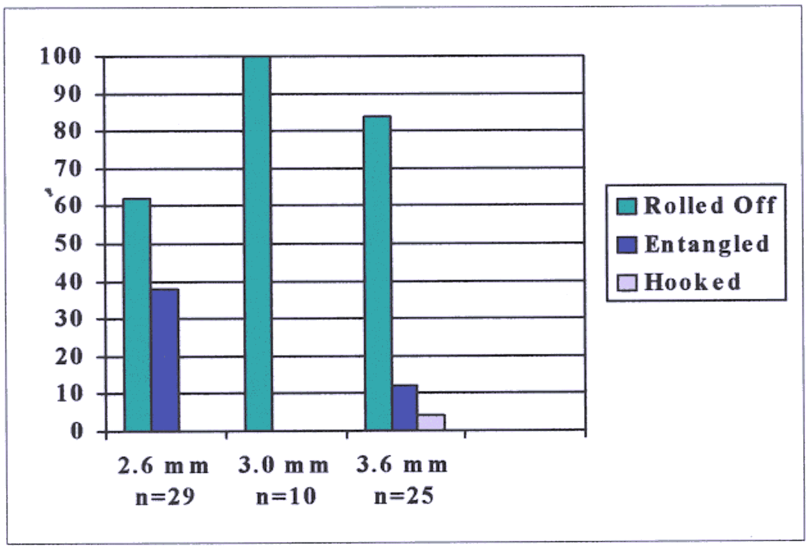

Table 5 Results from evaluation of monofilament diameter vs. turtle entanglement . n= number of turtle encounters with given monofilament.

Entanglement Evaluation #2:
Weighted gangions vs. non weighted gangions

This evaluation was conducted to examine the effect of weighted gangions on turtle entanglement. Eight gangion treatments were constructed from 2.6 mm monofilament and rigged with 60 gram lead swivels. Four each of 3.0 mm and 3.6 mm monofilament gangions without weights were placed along 2 legs of the array. Observations of turtle encounters were recorded as in evaluation #1.

Results

The results from this evaluation are presented in Table 6. When compared to the results from the un-weighted 2.6 mm gangions (Evaluation #1), the same monofilament diameter with 60 gram weights appeared to reduce the number of entanglements. The weighted 2.6 mm gangions had approximately the same amount of flex as that of the 3.6 mm gangions. Turtles encountering the weighted 2.6 mm gangions were better able to deflect the line off the end of their flipper before contacting the hook .

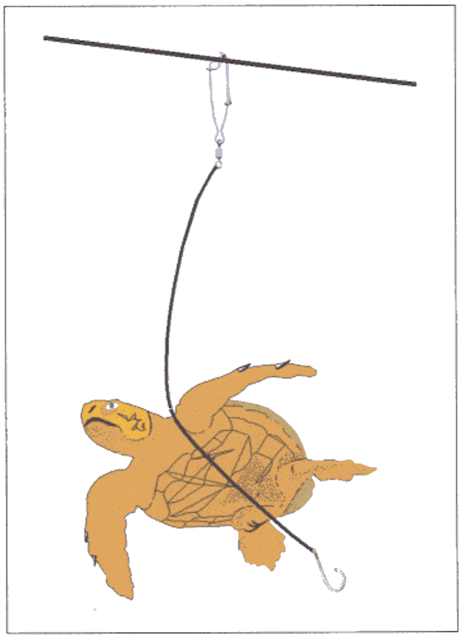

Figure 6 Typical turtle encounter with gangion with monofilament running over shoulder area

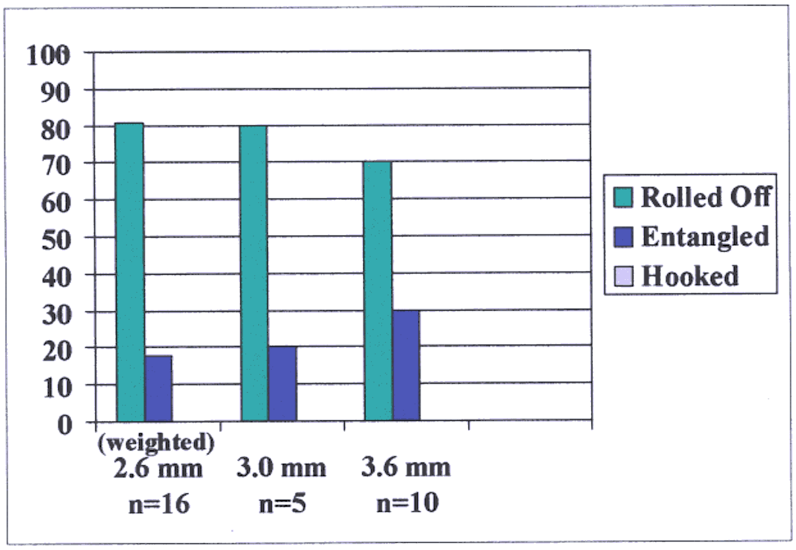

Table 6 Results from evaluation of weighted gangions vs. turtle entanglement

Entanglement Evaluation #3: *Funnel hook deflectors and turtle entanglement*

Hook deflectors (HD) were constructed from white and black plastic funnels and affixed to 2.6 mm monofilament gangions as shown in Figure 6, diagram A (mouth toward the hook).

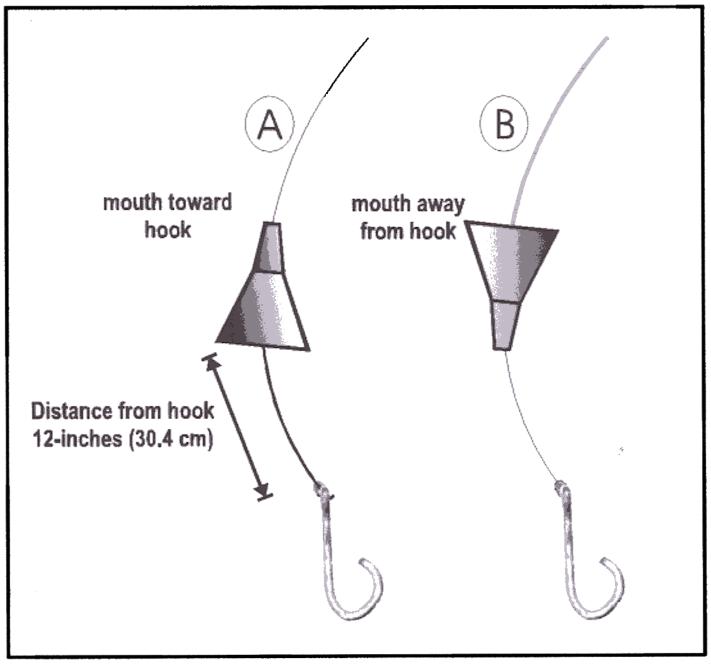

Figure 7 Funnel hook deflectors and orientations.

Funnel mouth sizes which were evaluated ranged from 4-inches (10 cm) to 1.5 inches (3.8 cm). Recorded observations included a successful deflection of the hook with the HD treatment. For this evaluation, all gangions were rigged with a funnel HD.

Results

The results from evaluations of funnel HD's are presented in Table 7. Events recorded as "rolled off" include both turtle contact with the funnel and subsequent deflection of the hook and events during which the monofilament simply rolled off the end of the flipper. In addition to acting as a "stopper" to prevent hooking, the funnel HDs seemed to create extra drag through the water, thereby causing the gangion to slough off the end of the flipper. Turtle encounters with 2.6 mm gangions fitted with funnel HD's resulted in considerably more deflections of the line and hook than those without funnel HDs.

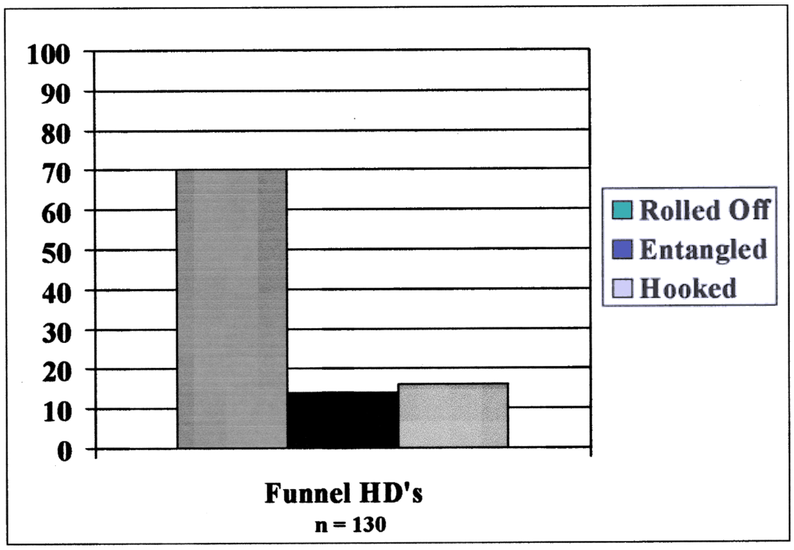

Table 7 Results from funnel HD evaluation

Entanglement Evaluation #4: *Funnel HD orientation vs. entanglement*

For this evaluation, 2.6 mm monofilament gangions were rigged with 1.5 inch (3.8 cm) funnel HDs. Eight gangions were rigged with the funnel mouth toward the hook (Figure 7, diagram A) and eight gangions with the funnel mouth toward the AK snap, or away from the hook (Figure 7, diagram B). The purpose of the test was to determine which funnel orientation had a greater effect on hook deflection.

Results

Both funnel orientations performed well in reducing entanglements. With the funnel mouth oriented toward the bait, the incidence of hooking was slightly greater (5 turtles). With the funnel mouth oriented toward the bait, the tapered end of the funnel did not present an effective "stop" to the flipper. Instead, the flipper tended to ride over the funnel thus allowing the monofilament between the funnel and the hook to reposition into the shoulder area of the turtle. While the effectiveness for reducing entanglement between the two orientations may seem obvious, the orientation may also have a significant effect on fish hooking and retention.

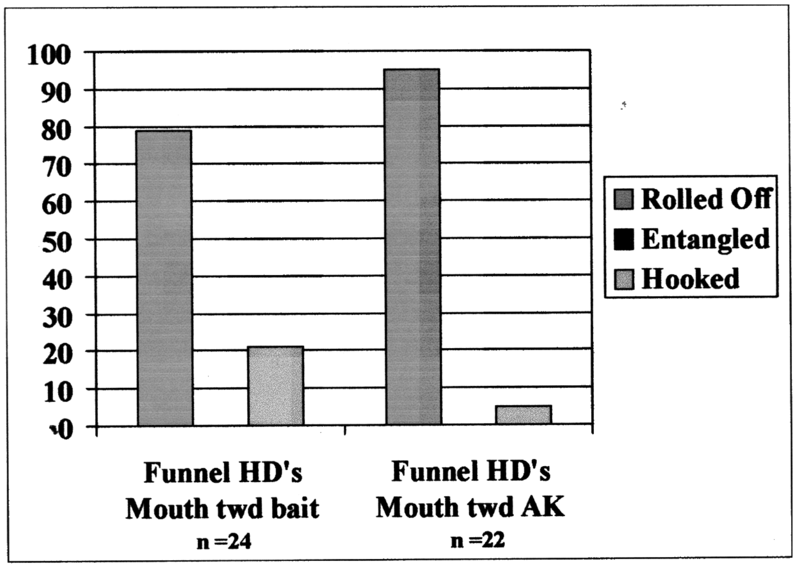

Table 8 Results from evaluation of funnel orientation and turtle entanglement.

Entanglement Evaluation #5: *Weedless-type HD vs. entanglement*

Weedless style hook guards were constructed from 180 lb test stainless steel fishing leader and fitted to barb-less 9/0 J-hooks as shown in Figure 7. Two styles of weedless hook guards were evaluated, 1) A full guard style which looped around the hook point, and 2.) a off-set style which placed the deflector wire to one side of the hook point. Eight 2.6 mm monofilament gangions with full guard weedless HD's and four 2.6 mm gangions with off-set weedless HD's were distributed along the mainline. Four gangions without HD's (modified 9.0 hooks only) were also distributed along the mainline.

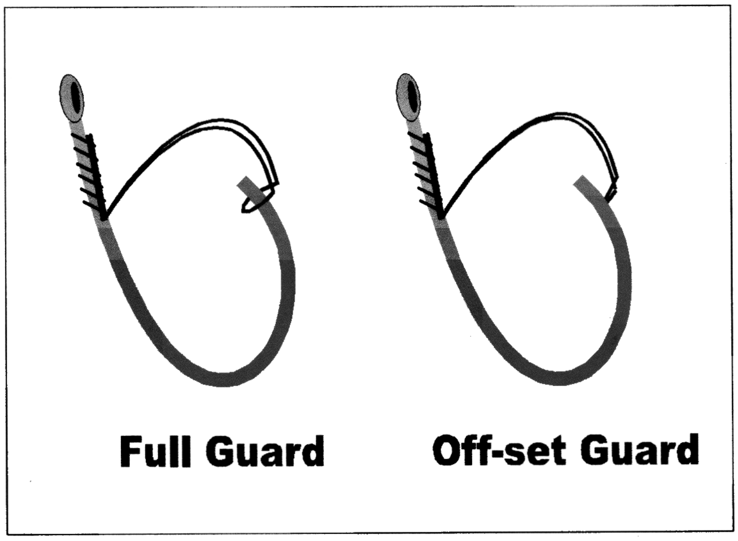

Figure 8 Weedless Style Hook Deflectors

Results:

The results from the evaluation of weedless style HD's are presented in Table 9.

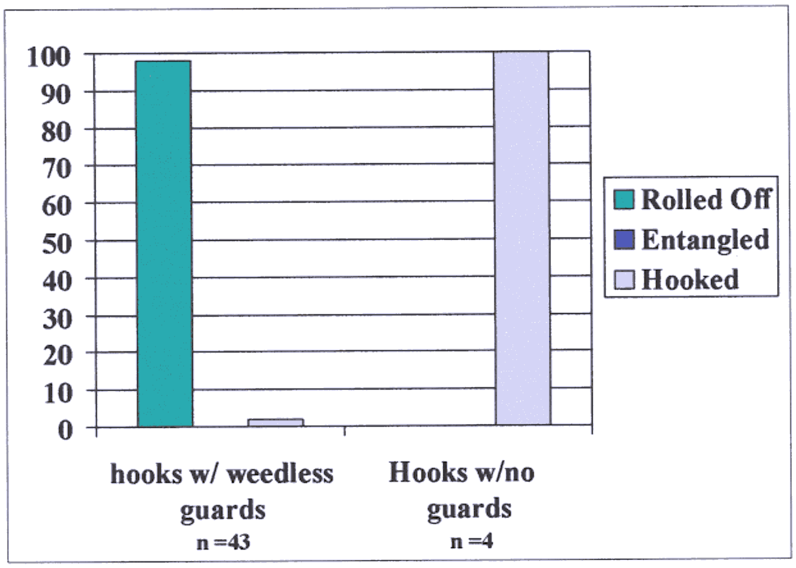

Table 9 Results from evaluation of weedless hook guards and turtle entanglement.

Both types of weedless hook guards worked well in deflecting the hook off the flipper. Those gangions with no hook guards, while representing only 1/4 of all gangions in the treatment, hooked each turtle which encountered them.

Observations of turtle interaction with longline gear components

Observations of turtle interaction with the gear other than entanglement was also recorded during the entanglement study. Other interactions which were recorded included, biting various gear components such as AK snaps, mainline, and modified hooks. Observers also noted was "tracking" behavior, or obvious following of the mainline and or gangions as the turtles traversed the pen. From 49 turtles which were observed during entanglement studies conducted in June and September, a total of 63 events were recorded as interaction with the gear other than entanglement. These events included 36 incidences of tracking, 10 incidences of biting the monofilament (mainline and gangions), and 12 incidences of biting the AK snaps, swivels and modified hooks and 5 incidences of biting the funnel HD (Table 10). Some turtles were not attracted to the gear at all, whereas others were obviously attracted to the shiny components of the gear such as AK snaps and swivels. Several turtles were observed to move along the longline array and "peck" at each AK snap, spending a minute or longer at each. Of the incidences of biting the funnel HD's, the funnels of choice were white in color. In each of the incidences, blue and black funnel colors were also available and randomly distributed in the longline array.

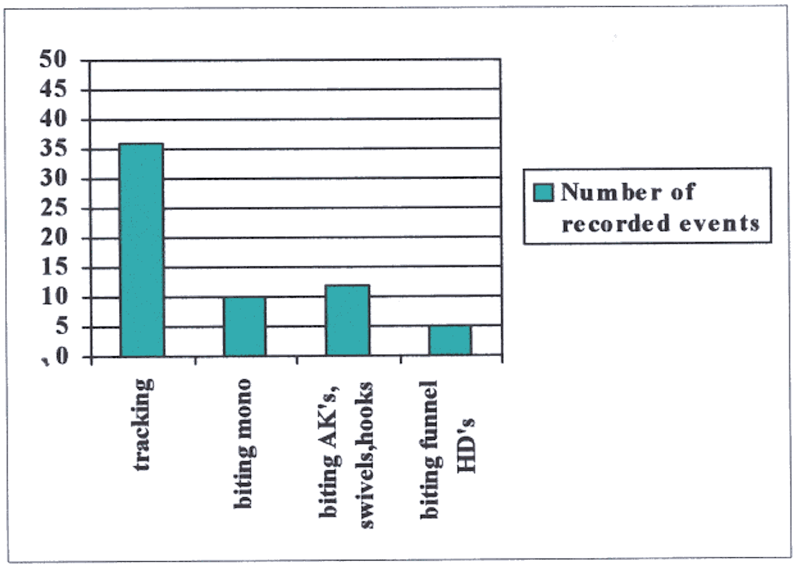

Table 10 Number and type of recorded interactions with longline gear other than entanglement

An evaluation of shark models as turtle deterrents

An evaluation of turtle reaction and behavior when exposed to a shark model was conducted during both June and September project periods. The aim of this evaluation was to examine the feasibility of using predator shapes as a means of preventing turtle encounters with longline gear. Two fiberglass shark models (taxidermy blanks) representing a Great White (*Carcharinus cacharias*) and a Tiger Shark *(Galeocerdo cuvieri*) were obtained from a local taxidermy shop. Each model measured approximately 56-inches (142 cm) in overall length. The blanks were realistically painted and floatation/weight were added to the body cavity to allow the models to float neutrally in the water column.

June observations

During the June project, the models were positioned in the experimental pen in a water depth of 6 feet approximately 3 feet off the bottom. Because the normal behavior of the turtles seemed to favor moving along the sides or perimeter of the pen, the model was placed along side of the pen to insure a turtle encounter. Water turbidity was approximately 3 feet (1 m) of visibility. Two turtles were placed in the pen and allowed to swim freely for 45 minutes with one model in the pen. Initially the turtles appeared to avoid the shark model, coming to within several feet of it before stopping, then changing the direction of their movement. At the end of the 45 minute period it appeared that the turtles had become somewhat acclimated to the model, moving around it rather than reversing direction. Turtles reacted similarly to both model types.

September Observations

A September evaluation was conducted by positioning the Great White model in the deep end of the pen (water depth 7-ft (2.1m) approximately 3 feet (1 m) off the bottom. Turtles which had not been fed for a 48 hour period were exposed to the model by "luring" them to it with a squid bait tied to a monofilament line. The lure bait was thrown in front of the turtle by an investigator at the surface. Once the turtle was attracted to the lure, the bait was pulled near the shark model. Water turbidity during this evaluation was approximately 4 feet (1.6 m).

Two turtles were exposed tot he Great White model in the above manner. When the turtles came to within 2 to 3 feet of the model they exhibited a strong avoidance reaction to the model, giving up their pursuit of the bait. The turtles quickly altered their swimming direction when the shark model came into view, turning sideways to it so that their full carapace was exposed. A total of 10 encounters were observed over a 45 minute period, each resulting in the same avoidance and flight behavior.

The differences in behavior observed between the June and September observations may be attributed to the following: 1.) Turtles used in the September had been deprived of food for a longer period (48 hours in September compared to 24 hours in June), 2.) Water clarity was somewhat better in September and , 3.) There were considerably more pinfish (*Lagodon rhomboides*) in the pens during the September tests. Pinfish were observed to avoid the shark model and would not pursue the squid bait when it came near it. Pinfish behavior near the shark may have acted as an additional cue to inducing avoidance by the turtles.

Discussion

Float Attraction

Some researchers theorize that loggerhead sea turtles may find the baited hook by first being attracted to the longline floats and then following the droplines down to the bait. In the June tests, captive reared sea turtles had an attraction to orange floats but not to white floats . During the September tests, the attraction to orange floats was not evident. The number of trials in the September test was less than half of the number in the June tests (34 trials vs. 15). Additional testing needs to be conducted to determine if other components of the float assembly may be attracting the turtles such as the AK snaps or the monofilament line. Some of the many other factors which may be involved could be the movement of the floats in the open ocean, occurrence of bait around the float and the effect of clearer water in the open ocean. The captive reared turtles used in our evaluations have not experienced the juvenile life stage where they may be attracted to floating objects in the open ocean. This missing part of their life cycle may skew the behavior of the captive reared turtles in that they do not have their natural attraction to floating objects.

Deep Hooking Avoidance Devices

The actual rate of mortality of sea turtles which have been captured on longlines and released alive is unknown. It is felt that the rate is significant, especially in those turtles which deeply swallow the hook into their throat or gut causing damage of internal organs. The deep hooking avoidance devices (DHAD) seem to have great promise in reducing deep hooking. Additional research is being planned to determine whether these fishing with the devices will still allow for the capture of the target species. The optimal size and shape of these devices still needs to be determined for optimum catch rates of target species and to limit deep hooking of sea turtles.

Monofilament Visibility

There are many uncertainties in why sea turtles may be attracted to longline gear. Some theories suggest that sea turtles may see the monofilament drop line and/or floats and are attracted to it. Turtles may follow this line down to the mainline and from there to the baited hooks on the gangions. If this is the case, a monofilament line which cannot easily be seen (i.e. stealth gear) may be of some benefit. Therefore the color of the monofilament line may be very important and choosing the least visible color for the particular component of the gear (drop lines, mainline, or gangion) may be of great benefit. The optimal color may vary according to the color of water in which it is fished. Alternatively, leatherback sea turtles tend to get entangled and subsequently foul hooked by the monofilament line. In this case, line which is of higher visibility might ward off a leatherback.

Turtle entanglement and deterrents

Our evaluations found that 2.6 mm monofilament gangions were more likely to entangle a turtle than gangions made of stiffer monofilament. When 60 gram weights were added to the 2.6 mm monofilament gangions the incidence of encounters which resulted entanglement was reduced. Funnel hook deflectors reduced the incidence of entanglement and hooking. Funnel HD's which were oriented with the mouth toward the AK snap resulted in more deflections of the gangion and fewer hooking incidents. The smallest funnel evaluated (1.5 inches in diameter) seemed to work as well as the largest (4-inches in diameter). This orientation may also be better for fish retention in that the tapered end of the funnel will be closer to the hook. Funnel HD's may also double as deep hooking avoidance devices if placed closer to the bait. Based on the September evaluations, further investigation of predator shapes as deterrents may be worthwhile. A possible next step may be to experiment with shark shapes or silhouettes constructed from flexible material which could be easily attached or detached from the longline.

Turtle attraction to gear components

These observations indicate that some turtles may be attracted to the shiny components of the gear. Biting of the AK snaps, swivels and hooks seemed to occur after the turtle had been exposed to the gear for a period greater than 15 minutes. Further investigation of turtle reaction to dark colored AK snaps and swivels may be worthwhile. One gear manufacturer has already developed prototype AK snaps in a flat black color. The high incidence of turtle tracking of the gear indicates that within our controlled setting, turtles were generally curious about the gear, and were fully capable of following it.

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